developer, and the amount chanced to be correct. All photography is done with objective and camera. In photographing the sun, the object is some ninety millions of miles off; in photographing a fluid inclusion in quartz, it is the 1/16th of an inch off—a mere question of detail. Most of these scientific photographs are far easier than the simplest everyday landscape.

A. R. HUNT.

Comets and Corpuscular Matter.

REFERRING to Prof. J. J. Thomson's article on "corpuscles" in your issue of May 10, it occurs to me that the behaviour of corpuscular matter described therein may have some bearing on cometary phenomena. May not the structure of comets to some extent be explained by assuming that their tails are composed of aggregations of negatively charged particles of extremely minute size, answering to the free corpuscular matter as defined by Prof. Thomson, and which to a large degree may be formed by a sort of "corpuscular dissociation," or detachment, taking place in the comet's nucleus when its temperature is elevated upon nearing the sun? Since Prof. Thomson's experiments indicate the presence of negatively charged matter in kathode rays having a much smaller mass than ordinary atoms, there is reason to believe that matter in this state has properties quite apart from matter in a much coarser state of atomic division. Postulating an electrostatic field as existing in interplanetary space, with the sun as a negative centre or source of electrostatic radiation, and assuming that a comet's tail is composed of these corpuscles, the gravitational force it may suffer, when in proximity to the sun, would perhaps be very small in comparison with the electrostatic force existing throughout the vast congregation of these extremely minute particles, and thereby account for the repulsion of the tails of comets when they approach the sun.

The nuclei of comets may be composed of matter in a much coarser state of subdivision, which, though endowed with positive or opposite electricity, is subject to gravitational influences which determine their course in the neighbourhood of the sun.

While the above is a partial re-statement of existing hypotheses, it may, I venture to suggest, be of interest in connection with Prof. Thomson's remarkable experiments on matter smaller than atoms.

F. H. LORING.

1 Champion Grove, Denmark Hill, S.E., May 18.

A NEW INSTRUMENT TO MEASURE AND RECORD SOUNDS.[1]

A DIRECT, absolute measurement of the intensity of sound at any point in the air must determine in ordinary units, such as kilogram-metres, the energy involved in the condensations and rarefactions of which the propagation of sound consists. But these pulsations follow each other so rapidly, and the amount of energy involved in even the loudest sound is so infinitesimal, that such measurement is attended with considerable difficulty; so much, indeed, that probably not a half-dozen laboratories in the world have any instrument whatever purporting to make direct, absolute measurements of the energy of sound.

We owe to Helmholtz ("Wissenschaftlische Abhandlungen," vol. i. p. 378) a mathematical theory by which we can determine the ratio between the energy of the pulsations of a tone just without, and that within a spherical Helmholtz resonator; to Lord Rayleigh we owe an expression for the energy of sound in terms of the condensation ("Theory of Sound," vol. ii. Sec. 245). Upon these two results this instrument (like Wien's, *Wied. Ann.* 1898, p. 834) is founded.

A pure tone is received into a spherical Helmholtz resonator, a portion of the walls of which is replaced by a small, circular, extremely thin glass plate, situated just opposite the mouth of the resonator. The pulsations within force this plate to vibrate with the tone's frequency; and if the natural pitch of the plate is made to approximate that of the resonator and tone, the amplitude of the plate's vibrations are rapidly multiplied. To make this amplitude a definitely measurable quantity, the sensitive plate carries at its centre a tiny mirror, which forms one of a system of mirrors constituting Michelson's refractometer (*Phil. Mag.* 1882, xiii. p. 236). A displacement of the little mirror from its position at rest amounting to a half wave length of light will cause a corresponding shifting to one side of the interference bands, so that each dark band will take the position before occupied by the next dark band. The width of the bands may be so adjusted that a telescope with micrometer eyepiece can easily subdivide each band into a hundred parts. Hence the displacement of the sensitive plate, while a tone is sounding, could be observed with great precision, if the eye could act with sufficient rapidity to mark the oscillation of any one band.

That, of course, is out of the question. But it is easy to compound this motion of the bands with another motion perpendicular to it (also in the focal plane), and thus to make the displacements visible. To do this, the interference bands are made to stand vertically in the field, and a screen with a narrow, horizontal slit is interposed in the line of sight; consequently the bands during silence appear in the telescope as a narrow, horizontal strip, composed of the bands reduced to square spots of dark and light. Now a small lens, forming the object-glass of the telescope, is mounted upon the end of one tine of a tuning fork, electrically driven, and having the pitch of the tune to be measured. During silence, the vertical vibration of the object-glass stretches out the strip of spots into a rectangle of long, vertical bands. But when the tone sounds, these bands arrange themselves diagonally across the same rectangle, the slope of the bands increasing with the intensity of the tone.

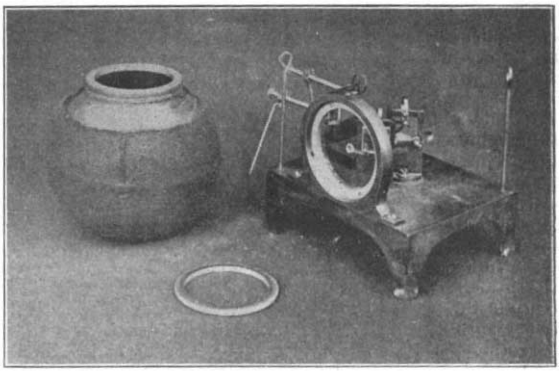

FIG. 1.—The refractometer. The resonator has been unscrewed from the supporting bracket, leaving the sensitive plate and tiny mirror in place.

The micrometer eyepiece can be rotated on its optical axis, and it is provided with a tangent screw for close adjustment. As it is rotated a vernier moves over a graduated arc, so that the angle of the slope (α) may be measured, as well as the height (Q) of the rectangle, the height (o) of the strip, and the width of five double bands. Putting $B = Q - o$, and $P =$ the displacement of a band, we have $P = B \tan \alpha$. The intensity of the tone is proportional to P^2, which is thus determined in mean wave-lengths of white light.

Thus far it has been tacitly assumed that the source of tone is at just the right distance from the receiving resonator for the vibrations of the sensitive plate to be in phase with those of the fork carrying the object-glass. But in ordinary work this agreement in phase

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[1] This instrument is described somewhat more fully than it is here in the *Monthly Weather Review*, July 20, 1899, published by the U.S. Department of Agriculture. We are indebted to the courtesy of its editor, Prof. Cleveland Abbe, for the accompanying illustrations.

rarely occurs, so a further modification is important. However, by simply loading the lens fork very slightly, we make the phases of the one oscillation overtake those of the other as slowly as we please. During agreement in phase the appearance of the bands will be that already described, with the slope (let us say) downward to the right. Two or three minutes after, when the two phases are opposite, the slope of the bands will be downward to the left. Between these two appearances confusion will reign, for the rectangle is then occupied by overlapping ellipses of changing eccentricity. But whenever the two oscillations are composed into a straight line there is abundance of time to measure the slope of the interference bands.

We have now attained only a relative measurement of intensity. But if we knew what maximum pressure within the resonator produced the observed amplitude of the sensitive plate, Rayleigh's expression together with Helmholtz's ratio would yield us the absolute intensity of the tone just outside the mouth of the resonator, which we seek. This pressure we do not know; we can, however, make a pretty close approximation to it. Let us be content, provisionally, with an error of about four parts in a thousand. Accordingly we will remove the sensitive plate from the resonator, in order to substitute for it a thicker plate, of natural pitch four octaves higher. Then we will cork the resonator, and produce a series of pressures within it by means of an air-pump. These pressures, measured statically with a water manometer, together with the corresponding displacements, furnish a table of the degree of approximation sought; so that by interpolation, when necessary, we may assign the pressure that has caused the amplitude, P, in any particular case, and thence obtain the energy of the tone in absolute units.

Of course, much pains must be taken to exclude all disturbing vibrations from the sensitive plate, whether transmitted through the air or through the floor and supports. Moreover, even the waves of the tone to be measured must be allowed to beat only upon the side of the plate which is within the resonator. Accordingly, heavy, padded boxes and piers of soft rubber are employed for the refractometer, for the tuning fork which carries the object-glass; and also for the instrument which produces the tone, as well as for the camera, both of which remain to be described. With these precautions, however, the result desired is very well attained, as is shown by careful tests. Moreover, the constancy and sensitiveness of this instrument promise to be highly gratifying.

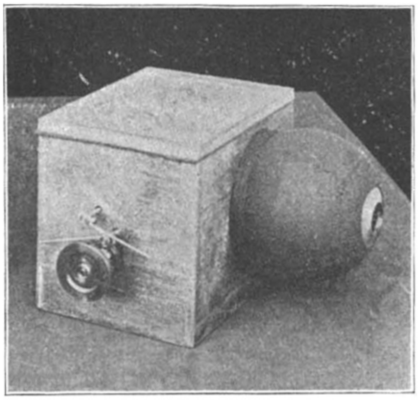


FIG. 2.—The refractometer boxed and ready for use. The resonator is covered with felt.

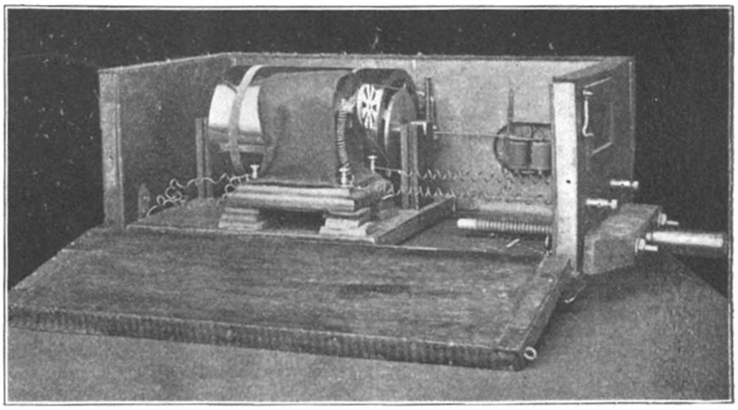


FIG. 4.—The open camera. The motor is shrouded to prevent its sparking from fogging the film. Adjustment of speed is accomplished by the aid of stroboscopic observation of the disc of black and white sectors, inspected through the square of ruby glass opposite. The electromagnet operates the arm which carries the shutter.

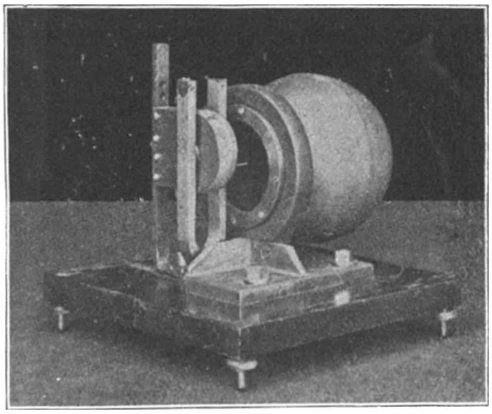
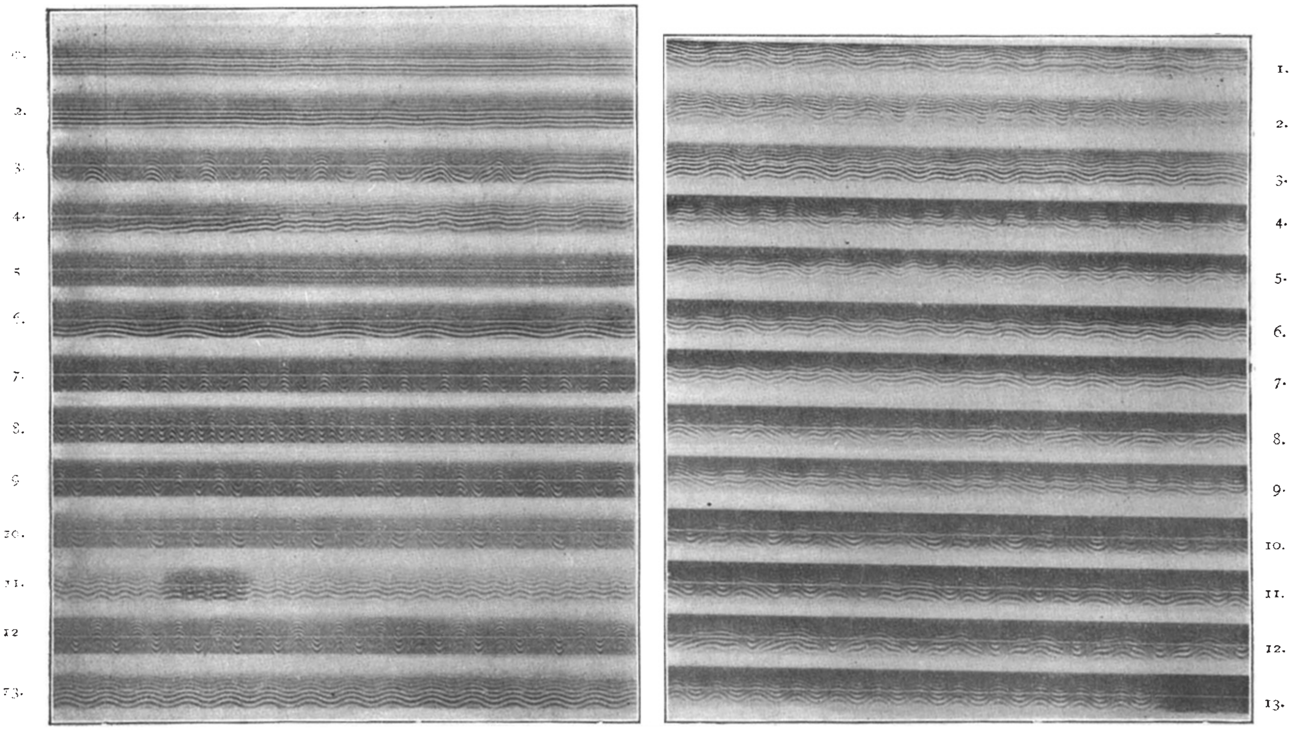


FIG. 3.—The source of tone, with its box removed.

For experimentation we require a source of sound that will produce a tone of great constancy and purity, but one whose intensity may be varied at will between wide limits. Moreover, the tone should issue from a small and definitely located area. It will be convenient, also, to have this instrument easily portable, so that it may be moved freely even while sounding. Such a source is obtained by causing a tuning fork to transmit its vibrations to a thin iron plate, which forms a portion of the walls of another spherical resonator; for the middle of one tine is rigidly connected with the centre of the plate. This combination is carefully tuned to give the tone required, and it is boxed so that only the mouth of the resonator protrudes. The fork is driven electrically, but its current is interrupted by the vibrations of a second fork, the two being in relay. The intensity of the tone depends, of course, upon the strength of the current which drives the source-fork, and this we may vary at will. Moreover, the intensity at the mouth of the source-resonator may be defined in terms of the current effective in producing it. These intensities are determined by means of the damping factors of the arrangement. The theory of this source as an independent, absolute measure of intensity is an extension (Sharpe, *Science*, 1899, p. 810) of that given by Lord Rayleigh for the tuning fork (*Phil. Mag.* 1894, vol. xxxviii. p. 365). This instrument makes a very pure and effective source of tone, simple in construction, and useful for a variety of purposes. A feeble current of a few hundredths of an ampere produces a tone that can be distinctly heard in every part of a building, 204 × 114 feet, four stories high, and containing ninety rooms. It may also be used under water.

To photograph and thus record for analysis a sound of any kind whatever, the resonator is removed by simply screwing it off, without disturbing the sensitive plate; and a camera is substituted for the telescope and eye. The window of the camera now forms the narrow slit, and a lens, placed between the window and the refractometer, focuses a narrow, horizontal strip of interference bands upon the photographic film. This film is wound about a cylinder (*cf.* Raps, *Wied. Ann.* 1893, p. 194) kept in rapid rotation by a small electric motor within the camera. The speed of this motor is kept constant by Lebedew's method (*Wied. Ann.* Band 59, p. 118). Consequently the lateral vibration of the bands caused by the sound, combined with the steady, vertical motion of the exposed portion of the film, is recorded in parallel, wavy lines. The shutter is opened for the time required for a single rotation of the cylinder by an electrical device. After each exposure the cylinder is moved in the direction of its axis by turning a screw from without. Thus a fresh portion of the film is brought under the shutter, without stopping the motion or opening the camera. In this way were taken the photographs of fork tones and vowels here given (Fig. 5). The photograph of a single tone from the source, whose intensity at the sensitive plate has been determined by the first method, affords a standard (viz. its amplitude) for determining the absolute intensity of every other sound photographed; while comparison with the wave-length appearing in the photograph of the tone of a standard fork gives the pitch of other sounds. BENJAMIN F. SHARPE.



1. Quiet. 2. Fanning I. 3. Fanning II. 4. Noise. 5. Flageolet. 6. Fork C_{128}. 7. Fork c_{256}. 8. Fork c'_{512}. 9. Forks C+c. 10. Forks C+c+c′. 11. Forks g+a. 12. Forks c+e+g+c′. 13. Tone source.

1. (a)h. 2. (o)h. 3. p(oo)l. 4. (a)te. 5. m(ee)t. 6. s(e)t. 7. (a)t. 8. (i)t. 9. (au)ght. 10. (e)re. 11. (u)se. 12. (u)rn. 13. Fork c_{256}.

FIG. 5.—Analyses of Fork Tones and Vowel Sounds.

NOTES.

As we go to press, a message from Sir Norman Lockyer at Santa Pola informs us that 130 volunteer observers have been obtained from H.M.S. *Theseus*. The instruments have been adjusted, and the Spanish authorities are assisting splendidly. The weather prospects are good.

MR. J. S. BUDGETT left Liverpool on Saturday last on his second expedition to the Gambia, where he is going in order to complete his studies of the fish-fauna of that colony, and especially to investigate the life-history and development of the abnormal fishes *Polypterus* and *Protopterus*. On reaching Bathurst, Mr. Budgett will proceed up the River Gambia to his former quarters on M'Carthy's Island, in the neighbourhood of which he has already ascertained that these fishes are found breeding during the rainy season. A memoir on some points in the anatomy of *Polypterus*, based on specimens obtained by Mr. Budgett during his first expedition, was read before the Zoological Society on May 8, and will shortly be published in the Society's *Transactions*.

AT a recent meeting of the British Ornithologists' Union and Club, under the presidency of Mr. F. D. Godman, F.R.S., the following resolution was unanimously adopted:—"That any member of the union directly or indirectly responsible for the destruction of nests, eggs, young or parent birds of any species mentioned below should be visited with the severest censure of the union and club." The birds referred to are the chough, golden oriole, hoopoe, osprey, kite, white-tailed eagle, honey buzzard, common buzzard, bittern and ruff.

THE committee of the Liverpool School of Tropical Diseases have decided to despatch, at an early date, an expedition to the Amazon to investigate yellow fever. The expedition will